

Temporal sequence of right and left atrial contractions during spontaneous sinus rhythm and paced left atrial rhythm

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The sequence of right and left atrial contractions was analysed in 8 patients during spontaneous sinus rhythm and paced left atrial rhythm. During sinus rhythm, the beginning or peak of the right atrial a wave invariably preceded the beginning or peak of the left atrial a wave by a median of 32 and 34 msec, respectively.

During paced left atrial rhythm, the beginning or peak of the right atrial a wave regularly followed the beginning or peak of the left atrial a wave by a median of 96 and 92 msec, respectively. The inversion of the normal sequence of atrial contractions may be used to confirm the existence of a spontaneous left atrial rhythm which otherwise can only be suspected by questionable electrocardiographic criteria. The increased time interval between atrial contractions during paced left atrial rhythm supports the hypothesis of the existence of specialized conduction pathways in the atria.

The electrocardiographic criteria for the differentiation of left atrial from coronary sinus and junctional rhythm were introduced by Mirowski, Neill, and Taussig (1963) and Mirowski (1966). Stimulation of the left atrium established that these criteria may be fallacious (Massumi and Tawakkol, 1967; Frankl and Soloff, 1968; Härtel and Louhija, 1968; Harris *et al.*, 1968; Lau *et al.*, 1970). Vectorcardiographic analysis of atrial activity and intracardiac electrograms were not sufficient to determine left atrial rhythm with certainty. Therefore, the existence of spontaneous left atrial rhythm remained debatable (James and Sherf, 1971; Selman and Edelstein, 1969).

It can be assumed that during left atrial rhythm the left atrium contracts before the right, since during spontaneous sinus rhythm the inverse sequence appears. By analysing the sequence of right and left atrial contractions, the existence of a spontaneous left atrial pacemaker in a few cases could be strongly suspected (Slany and Mösslacher, 1970; Belz, Olesch, and Heesemann, 1971; Mösslacher and Slany, 1972; Bernuth and Belz, 1972).

The purpose of this study was to analyse the sequence of atrial contraction during sinus rhythm and paced left atrial rhythm. If this sequence during paced left atrial rhythm should always be inverted

as compared to that during sinus rhythm, then simultaneous atrial pressure measurements would be a valuable tool for identification of spontaneous left atrial rhythm.

Subjects and methods

Eight patients (Table 1) with normal sinus rhythm were studied. During diagnostic right and left heart catheterization a 7 F Cournand catheter was introduced percutaneously into the right femoral vein and positioned in the right atrium. An 8 F Brockenbrough catheter was introduced into the same vein and advanced into the left atrium, either by puncture of the atrial septum or via a patent foramen ovale. In Case 1 who underwent coronary angiography because of severe angina pectoris a patent foramen ovale was found on routine right heart catheterization. Case 5 was clinically thought to have an atrial septal defect. Right heart catheterization, however, only revealed a patent foramen ovale without detectable shunting by oximetry and dye dilution curves. In the 3 patients with mitral stenosis the pulmonary arterial wedge pressure was unsatisfactory so that atrial septal puncture became necessary. The same procedure was also used to enter the left ventricle for pressure measurements and angiography when this could not be done from the aorta in the patients with aortic valve disease and coarctation.

For left atrial stimulation and pressure measurements, a microstimulation catheter (Stimutron) was advanced through the Brockenbrough catheter and its tip positioned in the area of the upper left pulmonary vein. The

TABLE 1 Summary of clinical data

Case No.	Age (yr) and sex	Diagnosis	Right atrium		Right ventricle systolic end-diastolic pressure (mmHg)	Left atrium		Left ventricle systolic end-diastolic pressure (mmHg)	Aorta	
			a/v x/y	Mean pressure (mmHg)		a/v x/y	Mean pressure (mmHg)		Systolic/diastolic pressure (mmHg)	Mean pressure (mmHg)
1	46 F	Patent foramen ovale	10/8 5/5	7	27/6	13/13 8/9	10	145/14	—	—
2	46 F	Mitral stenosis	8/10 6/5	7	47/7	13/20 12/9	14	158/9	157/96	110
3	40 M	Aortic valve disease; arterial hypertension	8/7 4/3	6	30/7	17/15 8/10	12	240/10	220/100	140
4	46 F	Mitral stenosis	8/6 0/3	4	60/6	28/30 18/18	22	—	—	—
5	34 F	Patent foramen ovale	3/2 0/1	1	24/2	5/4 1/1	3	110/8	—	—
6	41 M	Mitral stenosis	4/3 0/0	3	44/4	22/26 11/14	22	123/12	130/76	98
7	49 M	Aortic valve disease	11/6 2/6	6	30/8	19/16 6/8	12	170/15	105/55	75
8	18 M	Coarctation of aorta	4/3 2/2	3	30/5	8/6 3/5	6	110/10	—	—

pressures in both atria were simultaneously recorded during spontaneous sinus rhythm and during paced left atrial rhythm. For pressure measurements, Statham transducers P 23 Db and an Electronics for Medicine photographic recorder were used and for stimulation a battery powered pacemaker (Medtronic Pulses Generator Mod. 5837).

The left atrium was first paced just above the spontaneous heart rate. Subsequently the pacing rate was increased in steps of 10 beats a minute to a rate of 120 a minute. During both sinus rhythm and paced left atrial rhythm 10 cardiac cycles were analysed for the intervals between the beginning of the a waves (Δ_1) and the peak of the a waves (Δ_2) in the right and left atrium, a positive Δ indicating that the right atrial a wave preceded the left atrial a wave and vice versa for a negative. The mean values of the 10 cycles were calculated.

The difference in frequency response of the catheters used was assessed in each patient at the end of each study by simultaneous recording of right atrial pressure through both systems and measured as the delay with which phasic events of the pressure curves were inscribed through the Stimutron catheter. This delay ranged from 10 to 40 msec (median 28 msec). The individual value was subtracted from Δ_1 and Δ_2 obtained from the respective patient.

The median differences and ranges of Δ_1 and Δ_2 during sinus rhythm and paced left atrial rhythm were determined and the Wilcoxon matched pairs signed rank test was used to test the statistical significance of Δ_2 .

Results

The results of the measurements during sinus rhythm and during the lowest possible rate of paced left atrial rhythm are summarized in Table 2. In all patients the right atrial a wave preceded the left atrial a wave during sinus rhythm and followed it during paced left atrial rhythm (Fig.). The median interval between the beginning of the right and left atrial a waves (Δ_1) was 32 msec during sinus rhythm and -96 msec during paced left atrial rhythm. The median interval between the peak of the right and left atrial a waves (Δ_2) was 34 msec during sinus rhythm and -92 msec during paced left atrial rhythm. The inversion of the sequence of the peaks of the right and left atrial a waves during paced left atrial rhythms is significant at a level of $P < 0.01$.

An increase in the frequency of left atrial pacing did not show a significant change in Δ_1 and Δ_2 .

Discussion

It has long been known that the right atrial contraction precedes the left one during sinus rhythm, as indicated by the sequence of right and left atrial a waves (Fredericq, 1906; Bachmann, 1916; Lagerlöf and Werkö, 1948; Bayer, Loogen, and Wolter, 1967). It may be postulated that inversion of this

TABLE 2 Summary of values in 8 patients during spontaneous sinus rhythm and paced left atrial rhythm

Case No.	Spontaneous sinus rhythm			Paced left atrial rhythm		
	$\Delta 1$	$\Delta 2$	Heart rate	$\Delta 1$	$\Delta 2$	Heart rate
1	+9	+39	73	-130	-170	74
2	+18	+13	105	—	-120	95
3	—	+5	46	-56	-46	58
4	+55	+29	90	-60	-85	100
5	+76	+61	64	-96	-29	78
6	+51	+104	55	-46	-58	72
7	+9	+42	64	-140	-99	68
8	+32	+25	90	-111	-98	98
Median	+32	+34		-96	-92	
Range	+9 to +76	+5 to +104		-46 to -140	-29 to -170	

$\Delta 1$ = interval between beginning of right and left atrial a waves in msec.

$\Delta 2$ = interval between peaks of the right and left atrial a waves in msec.

Positive Δ = right atrial a wave precedes the left.

Negative Δ = right atrial a wave follows the left.

$\Delta 1$ and $\Delta 2$ in msec.



FIG. Simultaneous right and left atrial pressure tracings and electrocardiographic leads II and III during spontaneous sinus rhythm (A) and paced left atrial rhythm (B) in Case 8. During spontaneous sinus rhythm the right atrial a waves precede the left atrial a waves, while during paced left atrial rhythm the left atrial a waves precede the right. a.s. = pressure in left atrium; a.d. = pressure in right atrium.

sequence of atrial contractions indicates a left atrial pacemaker.

Such an inversion of the sequence of atrial contractions during left atrial pacing is evident from the experimental data presented.

These observations lead us to conclude that a left atrial pacemaker which can only be suspected by electrocardiographic criteria, can be confirmed by simultaneous pressure measurement in both atria.

Comparison of time intervals between atrial contractions revealed another interesting observation: the interval between a waves during paced left atrial rhythm is about 3 times longer than during sinus rhythm (Table 2). This supports the hypothesis of the existence of specialized pathways conducting excitation from the sinus node through the atria (James and Sherf, 1971). The increased time interval between left and right atrial contraction during paced left atrial rhythm suggests excitation spreading predominantly over muscle fibres with a slower conduction velocity than that of the specialized conduction pathways used during sinus rhythm.

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